MODEL 109 TEMPERATURE PROBE
INSTRUCTION MANUAL

REVISION: 4/03

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CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

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Model 109 Temperature Probe

1. General

The 109 Temperature Probe uses a thermistor to measure temperature. Custom lead lengths are available up to 1000 ft.

The 109 probe is designed for use with the CR200 series datalogger which has a special instruction for measuring it. The probe can also be measured with other Campbell Scientific dataloggers using generic measurement instructions.

The 109 Temperature Probe is designed for measuring air/soil/water temperatures. For air temperature, a 41303 radiation shield is used to mount the 109 Probe and limit solar radiation loading. The probe is designed to be buried or submerged in water to 50' (21 ps).

1.1 Specifications

Temperature Measurement Range:	-50° to +70°C
Thermistor Interchangeability Error:	Typically <±0.2°C over 0°C to 70°C; ±0.5 @ -50°C
Temperature Survival Range:	-50°C to +100°C
Linearization Error:	The Steinhart and Hart equation used to calculate temperature is fit to the range of 0 to 70°C; maximum error is 0.03°C at -50°C.
Time Constant In Air:	Between 30 and 60 seconds in a wind speed of 5 m s^{-1}

NOTE The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and UV degradation. However, this jacket will support combustion in air. It is rated as slow burning when tested according to U.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

2. Accuracy

The overall probe accuracy is a combination of the thermistor's interchangeability specification and the accuracy of the bridge resistor. The Steinhart and Hart equation used to calculate temperature has a negligible error (Figure 2-1). In a "worst case" the errors add to an accuracy of ±0.6°C over the range of -50° to 70°C and ±0.25°C over the range of -10°C to 70°C. The major error component is the interchangeability specification of the thermistor. The bridge resistor has a 0.1%

tolerance with a 10 ppm temperature coefficient. Figure 2-2 shows the possible worst case probe and measurement errors. Note that at temperature extremes the possible error in the CR200 measurement may be greater than the error that may exist in the probe.

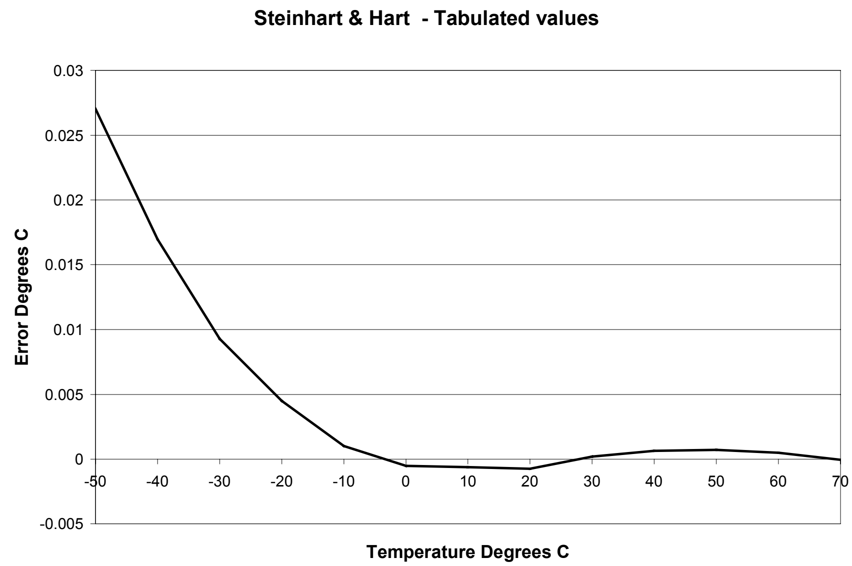

FIGURE 2-1. Steinhart and Hart

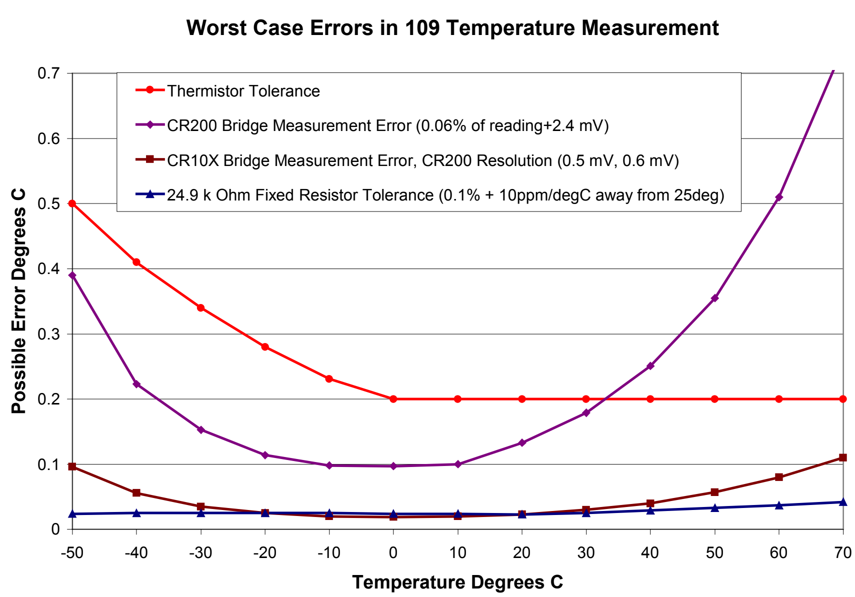

FIGURE 2-2. Possible Errors

3. Installation and Wiring

For air temperature measurement, the 109 must be housed inside a radiation shield when used outdoors. The 41303 Radiation Shield (see Figure 3-1) mounts to a CM6 or CM10 tripod. The UT018 mounting arm and UT6P Radiation Shield mount to a UT30 tower.

The standard lead length of 6 feet and 9 feet allow the 109 to be mounted at a 2 meter height on the CM6/CM10 tripod or the UT30 tower respectively.

Connections to the datalogger for the 109 are shown in Figure 3-2 and Table 3-1.

The number of 109 probes per excitation channel is physically limited by the number of lead wires that can be inserted into a single excitation terminal (approximately 6).

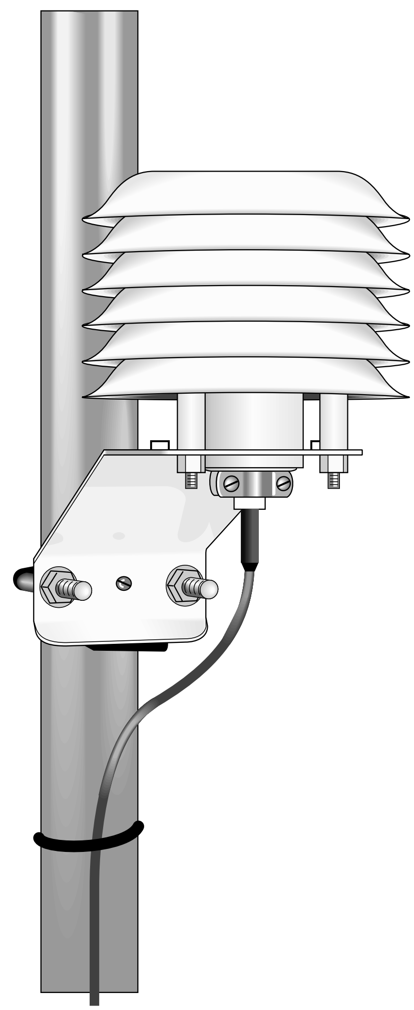

FIGURE 3-1. 109 and 41303 Radiation Shield on a CM6/CM10 Tripod Mast

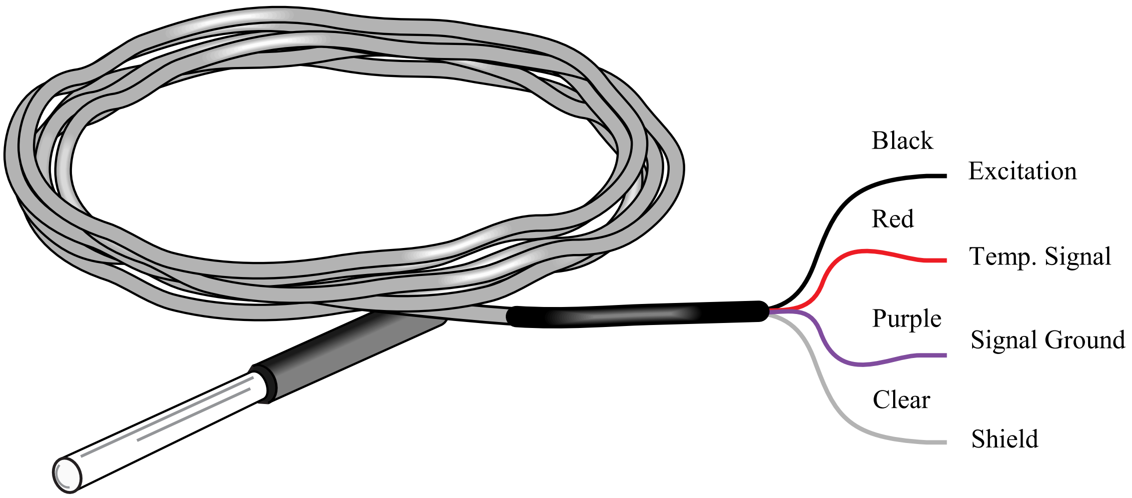

FIGURE 3-2. 109 Probe Datalogger Connections

TABLE 3-1. Sensor Wiring

Color	**Function**	**CR200, CR5000, 21X, CR7,CR23X**	**CR10(X), CR510**
Black	Excitation	Switched Excitation	Switched Excitation
Red	Signal	Single-Ended Channel	Single-Ended Channel
Purple	Signal Ground	⏚	AG
Clear	Shield	⏚	G

4. Programming

This section is for users who write their own datalogger programs. A datalogger program to measure this sensor can be created using Campbell Scientific's Short Cut Program Builder software. You do not need to read this section to use Short Cut.

In the CR200 series dataloggers, Instruction Therm109 is used to measure temperature. Therm109 provides excitation, makes a single ended voltage measurement, and calculates temperature.

A multiplier of 1.0 and an offset of 0.0 yields temperature in Celsius. For Fahrenheit, use a multiplier of 1.8 and an offset of 32.

TABLE 4-1. Wiring for Example Program

Color	**Function**	**CR200**
Black	Excitation	Switched Ex Channel 1
Red	Signal	Single-Ended Channel 3
Purple	Signal Ground	⏚, AG on CR10X
Clear	Shield	⏚

The Therm109 instruction has the following form:

Therm109 (Dest, Repetitions, SE Chan, Ex Chan, Multiplier, Offset)

Example 1. Sample Program for CR200 Series Datalogger

```
'CR200 Series Datalogger

'This example program measures a single 109 Thermistor probe
'once a second and stores the average temperature every 10 minutes.

'Declare the variable for the temperature measurement
Public Air_Temp

'Define a data table for 10 minute averages:
DataTable (AvgTemp,1,1000)
    DataInterval (0,10,min)
    Average (1,Air_Temp,0)
EndTable

BeginProg
    Scan (1 ,sec)
        'Measure the temperature:
        Therm109 (Air_Temp,1,3,Ex1,1.0,0)
        Call the data table:
        CallTable AvgTemp
    NextScan
EndProg
```

The next example is for the CR5000 datalogger. See Section 6 for a discussion of the measurements and processing involved.

Example 2. Sample Program for CR5000 Datalogger

```
'CR5000

'This example program measures a single 109 Thermistor probe
'once a second and stores the average temperature every 10 minutes.

'Declare the variable for the temperature.
Public Air_Temp
'Declare variables for the raw measurement, thermistor resistance, and ln(resistance):
Dim V_Vx, Rtherm, lnRt

'Define a data table for 10 minute averages:
DataTable (AvgTemp,1,1000)
    DataInterval (0,10,min,10)
    Average (1,Air_Temp,IEEE4,0)
EndTable
```

```
BeginProg
    Scan (1 ,sec,5,0)
        'Measure the 109 probe. The result is V/Vx:
        BrHalf (V_Vx,1,mV5000,3,Vx1,1,5000,True ,0,_60Hz,1.0,0)
        'Calculate reistance:
        RTherm=24900*(1/V_Vx-1)
        'Calculate the natural log of the resistance:
        lnRt=Log(Rtherm)
        'Apply the Steinhart and Hart equation and convert to degrees C in one step:
        Air_Temp=1/(1.129241e-3+2.341077e-4*lnRt+8.775468e-8*(lnRt^3))-273.15
        'Call the data table:
        CallTable AvgTemp
    NextScan
EndProg
```

The following example is for the CR10X datalogger. See section 6 for a discussion of the measurements and processing involved. Note that the polynomial instruction, 55, is used to apply the Steinhart and Hart equation. Instruction 55 does not allow entering the coefficients with scientific notation. In order to use this instruction with as much resolution as possible, the ln resistance term is pre scaled by 10^{-3}. This allows the first order coefficient (B) to be multiplied by 10^{3}, and the 3rd order coefficient (C) to be multiplied by 10^{9}.

```
;{CR10X}
;
*Table 1 Program
  01: 1           Execution Interval (seconds)

1:  AC Half Bridge (P5)
  1:   1          Reps
  2:   25         2500 mV 60 Hz Rejection Range
  3:   3          SE Channel
  4:   1          Excite all reps w/Exchan 1
  5:   2500       mV Excitation
  6:   1          Loc [ V_Vx      ]
  7:   1.0        Mult
  8:   0.0        Offset

2:  Z=1/X (P42)
  1:   1          X Loc [ V_Vx      ]
  2:   2          Z Loc [ Vx_V      ]

3:  Z=X+F (P34)
  1:   2          X Loc [ Vx_V      ]
  2:   -1         F
  3:   3          Z Loc [ Vx_V_1    ]

4:  Z=X*F (P37)
  1:   3          X Loc [ Vx_V_1    ]
  2:   24900      F
  3:   4          Z Loc [ Rtherm    ]
```

```
5:  Z=LN(X) (P40)
   1:    4            X Loc [ Rtherm    ]
   2:    5            Z Loc [ lnRt      ]

6:  Z=X*F (P37)
   1:    5            X Loc [ lnRt      ]
   2:     .001        F
   3:    6            Z Loc [ Scal_lnRt ]

7:  Polynomial (P55)
   1:    1            Reps
   2:    6            X Loc [ Scal_lnRt ]
   3:    7            F(X) Loc [ 1_Tk      ]
   4:    .001129      C0
   5:    .234108      C1
   6:    0.0          C2
   7:    87.7547      C3
   8:    0.0          C4
   9:    0.0          C5

8:  Z=1/X (P42)
   1:    7            X Loc [ 1_Tk      ]
   2:    8            Z Loc [ Tk        ]

9:  Z=X+F (P34)
   1:    8            X Loc [ Tk        ]
   2:    -273.15      F
   3:    9            Z Loc [ Air_Temp  ]

10:  If time is (P92)
   1:    0            Minutes (Seconds --) into a
   2:    10           Interval (same units as above)
   3:    10           Set Output Flag High (Flag 0)

11:  Real Time (P77)
   1:    110          Day,Hour/Minute (midnight = 0000)

12:  Average (P71)
   1:    1            Reps
   2:    9            Loc [ Air_Temp  ]

*Table 2 Program
   02:  0.0000        Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

5. Maintenance and Calibration

The 109 Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris.

6. Measurement Details

Understanding the details in this section are not necessary for general operation of the 109 Probe with CSI's dataloggers.

The Therm109 Instruction outputs a 2500 mV excitation and measures the voltage across the 24.9 K resistor (Figure 6-1). The thermistor resistance changes with temperature.

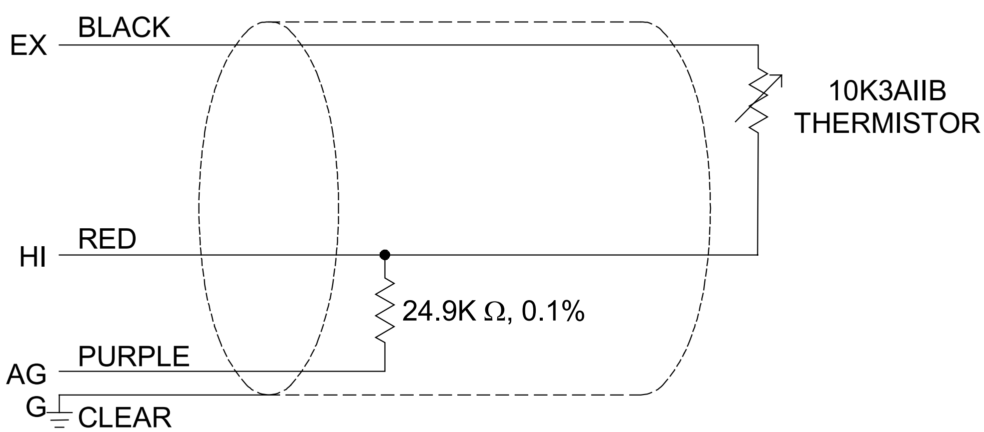

FIGURE 6-1. 109 Thermistor Probe Schematic

The measured voltage, V, is:

$$V = V_{EX} \frac{24{,}900}{24{,}900 + R_t}$$

Where V_{EX} is the excitation voltage, 24,900 ohms is the resistance of the fixed resistor and R_t is the resistance of the thermistor

The resistance of the thermistor is:

$$R_t = 24{,}900\left(\frac{V_{EX}}{V} - 1\right)$$

The Steinhart and Hart equation is used to calculate temperature from Resistance:

$$T_K = \frac{1}{A + B\ln(R_T) + C(\ln(R_T))^3}$$

Where T_K is the temperature in Kelvin. The Steinhart and Hart coefficients used in the CR200 Therm109 instruction are:

$A = 1.129241 \times 10^{-3}$
$B = 2.341077 \times 10^{-4}$
$C = 8.775468 \times 10^{-8}$